FLUOR DANIEL GTI

DRAFT

FEASIBILITY STUDY REPORT

General Motors-Allison Gas Turbine Plant 10 # 6991004
700 North Olin Avenue
Indianapolis, Indiana

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Prepared For
General Motors Corporation
485 West Milwaukee Avenue
Detroit, Michigan 48202

Prepared By:
Fluor Daniel GTI, Inc.

Tom Sichz
Engineer

Bernard A. Lauctes, PE
Lead Engineer

Gianni Chieruzzi, PE, PG
Senior Hydrogeologist

Reviewed/Approved By:
Fluor Daniel GTI, Inc.

Andrew A. Gremos, CPG, CHMM
Operations Manager

David E. Arnold, CPG
Senior Project Director

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~~PREPARED AT GMC COUNSEL'S REQUEST~~

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EXECUTIVE SUMMARY

Fluor Daniel GTI has prepared a Feasibility Study report for the former Allison Plant 10 located at 700 North Olin Avenue in Indianapolis, Indiana. This scope of work has been completed, when considered as a whole, to be consistent with the National Contingency Plan as referenced in 40 CFR 300.700 (Subpart H-Participation by Other Persons). The purpose of the study was to evaluate remediation cleanup goals for groundwater and soil, develop and screen possible remediation technologies, present results of treatability investigations, and provide a detailed analysis of selected remediation technologies.

Site-specific human health risks were calculated for the site using IDEM and Environmental Protection Agency (EPA) risk assessment methodology. No soil carcinogenic risks for non-residential exposures to soils exceeded the $1x 10^{-5}$ target risk level. On-site soil contaminants of interest (COI) concentrations found do not appear to pose a significant human health threat. No off-site soil COI were identified that required assessment.

Based on the noted exceedances of the Tier II Residential Cleanup Goals at property boundaries and/or at off-site locations, it is apparent that potentially unacceptable risks are posed by potential direct contact (i.e., ingestion) groundwater exposures to off-site residents in the immediate vicinity of the subject site. However, an evaluation of volatilized vapor from groundwater to indoor air using data from an off-site well posed no significant human health threat for offsite residents. No on-site groundwater COI were identified that required assessment.

The surface water non-carcinogenic risks were below the EPA's target hazard index of 1.0. Cis-1,2-dichloroethene, the only surface water COI, does not have carcinogenic toxicity constants. Therefore, no surface water carcinogenic risk levels were estimated. Off-site surface water COI concentrations found do not appear to pose a significant human health threat.

There are two major sources of organic constituents at the Plant 10 site: the principal source area is located near the northwestern corner of the property , and a secondary source area is located near the southeastern corner of the property . The direction of groundwater flow is generally toward the southeast in the western portion, and toward the south in the southeast portion of the site. As a result, the point of regulatory compliance is the southern and southeastern boundaries of the site. These property boundaries abut the City of Indianapolis Property and residential areas, respectively.

Remediation cleanup goals were determined for groundwater and soil in two phases. The objective of the first phase was to determine the maximum concentration of contaminants of interest (COI) that could be left in groundwater and not exceed Federal maximum contaminant levels (MCLs) for drinking water at the compliance point. The second phase determined the maximum concentration of COIs that could be left in the soil and, due to leaching, not exceed the groundwater cleanup goals established in the first phase.

The groundwater cleanup goals for the southeastern area were set at MCLs since little attenuation is expected to occur in the aquifer between the source area and the compliance point. The groundwater cleanup goals are 5 ug/L for trichloroethylene (TCE), 70 ug/L for cis-1,2-dichloroethene (cis-1,2-DCE), and 2 ug/L for vinyl chloride (VC). In the western area, some attenuation between the source and the compliance point will occur. As a result, groundwater cleanup goals are based on the results of analytical modeling with 15 ug/L for TCE, 170 ug/L for cis-1,2-DCE, and 5 ug/L for VC.

Soil cleanup goals were determined using the SESOIL analytical model. Based on the calculated groundwater cleanup goals, the model was used to determine applicable soil cleanup goals. Based on the results of the modeling and consideration of direct-contact exposures, the soil cleanup goals in the southeastern area are 24,182 ug/kg TCE, 181,425 ug/kg cis-1,2-DCE, and 300 ug/kg VC. In the western area, the goals are 43,528 ug/kg TCE, 259,605 ug/kg cis-1,2-DCE, and 300 ug/kg VC.

Remediation alternatives considered for this site fall under two areas of classification. The first is non-treatment of impacted soil and groundwater and the second is combined soil and groundwater treatment. Based on time to cleanup and potential institutional controls, the non-treatment options were not considered applicable. In addition, a monitor-only approach would not reduce the mobility, destroy, or reduce the volume of contaminants.

Of all the alternatives for remediation, the two which are most technically feasible are air sparge and soil venting (AS/SV) and soil venting with groundwater extraction .

Based on preliminary engineering calculations, the cost for capital purchases, installation, and operation and maintenance (O&M) for one year of the AS/SV system could range from $410,000 to $460,000. Annual O&M of the system could range from $65,000 to $95,000. These estimates do not account for the possibility of off-gas treatment of vapors. The cost for capital purchases, installation, and operation and maintenance (O&M) for one year of the groundwater extraction/SV system could range from $400,000 to $510,000. Annual O&M of the system could range from $90,000 to $110,000.

A SV/AS pilot test was conducted at the site on February 24, 1997. The test results suggest that this technology is feasible given the site conditions.

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1.0 INTRODUCTION

Fluor Daniel GTI, Inc.(Fluor Daniel GTI) has completed the following Feasibility Study (FS) for the Allison Engine Company, Plant 10 in Indianapolis, Indiana. A site location map is shown on **Figure 1**. This scope of work has been completed, when considered as a whole, to be consistant with the National Contingency Plan as referenced in 40 CFR 300.700 (Subpart H-Participation by Other Persons). The primary objective of the FS was to develop and evaluate appropriate remedial alternatives for contaminants of interest (COI) identified in the Remedial Investigation.

1.1 Background Information

1.1.1 Site Description

The subject property is the site of the former General Motors Corporation Allison Gas Turbine Division (AGT) Plant 10. This plant was purchased by General Motors from BHT Corporation (BHT) for use as a warehouse for obsolete machines, tooling, and fixtures in 1973. Prior to 1973, the facility was operated as a carburetor remanufacturing and brake overhaul facility by BHT. The original building was constructed in 1956 and renovated in 1970, doubling the floor space. The facility was used as a warehouse by General Motors until the mid 1980s at which time it became part of the AGT Division and continued to be managed as a warehouse. The property was then sold to The Allison Engine Company in December 1993 as part of the sale of AGT.

The site is occupied by a single warehouse. The area surrounding the warehouse is covered by asphalt and concrete. The western and southern sections of the property are grass with wooded areas. A site map showing salient site features is presented as **Figure 2.**

The property is zoned industrial and is currently occupied by Genuine Parts Company for use as a warehouse and distribution center. Land use in the surrounding area of the site is mixed use with zoning predominantly residential, general business, and industrial. The property is bordered by a wooded area, Little Eagle Creek, and Michigan Meadows Apartments to the south, a residential neighborhood to the east, a city park (Olin Park) to the north, and Holt Road and an Allison Transmission Plant to the west. Features of the surrounding area are presented on the Vicinity Map **(Figure 3)**.

The site is located on the southwest side of Indianapolis, Indiana on the Tipton Till Plain. The surface topography over most of the site is relatively flat. The southern third of the site slopes moderately to the south, towards Little Eagle Creek. Surface elevations at the site range from approximately 715 feet to 705 feet near Little Eagle Creek to the south. The subsurface of the site area is characterized by two thick layers of sand separated by a layer of silty clay. Another discontinuous layer of silty clay is found at the surface. The lower sand unit was not encountered at the maximum depth of penetration (65 feet) in the western area. Based on a comparison to published data, the two sand units are assumed to be the middle and lower confined aquifers of Meyer et al.,1975. The intermediary silty clay unit ranges in thickness from approximately 8 feet to greater than 33 feet. According to Meyer et al. (1975), this clay layer acts as a semipervious confining bed (aquitard).

Based on data collected during three gauging events in 1995 and 1997, groundwater occurs at elevations ranging from 698.92 to 703.75 feet in the shallow water bearing unit, 698.83 to 701.00 feet in the lower sand unit, and 689.10 to 700.68 feet in the intermediary clay unit. Groundwater elevation data indicates groundwater flows generally towards the south (Little Eagle Creek). A comparison of groundwater elevations in the three well clusters (MW-153, MW-202, and MW-302; MW-150 and MW-200; and MW-151, MW-201, and MW-301) indicated a downward vertical hydraulic gradient in the western portion of the site and east of the plant. An upward hydraulic gradient was observed offsite to the southeast. Rising head permeability tests indicated average hydraulic conductivities of 137 feet per day in the shallow sand unit, 8.7 feet per day in the lower sand unit, and 0.012 feet per day in the intermediary clay. Based on the low hydraulic conductivity of the intermediary unit, it appears to act as an aquitard between the aquifers.

Fluor Daniel GTI obtained all available drilling logs of domestic water wells on record at the Indiana Department of Natural Resources, Division of Water. A total of 160 domestic wells were identified as being located within a one-mile radius of the subject site, the nearest of which lies approximately 1,000 feet north (upgradient) of the property. The wells are completed within limestone bedrock, clay, or sand and gravel units at depths ranging from 30 to 270 feet below grade (bg). Records indicate the Allison Transmission Plant across Holt Road to the west has two water supply wells, the nearest of which lies approximately 1,600 feet northwest of the site (cross-gradient). The majority of the water supply wells identified are located to the north, west, and south of the site. A total of 47 municipal or high capacity wells were identified as being located within a two mile radius of the subject site, with 17 of those located within a one mile radius. The nearest of these wells lies approximately 1,400 feet northwest of the site along Little Eagle Creek (cross-gradient). A house-to-house survey of local residences along the east side of Olin and the west side of Luett Avenues was conducted by the Marion County Health Department (MCHD) in December, 1996. A single domestic well was located at 709 North Olin Avenue. The construction of the well is unknown. This well was not identified during the well search conducted at the Department of Natural Resources. Only well logs completed by the drillers and submitted to IDNR are found in the IDNR's files. The approximate location of this domestic well is provided on **Figure 3**. The well was sampled by MCHD on January 2, 1997. The analytical results indicate that volatile organics are not present in this water supply.

Potable water is supplied to the area by the Indianapolis Water Company (IWC). The water supply is drawn from numerous wells in the area, the majority of which are located along Eagle Creek approximately 1.5 miles west (upstream) of the subject site. A discussion with the Supervisor of Customer Contact at IWC indicated that residences across Olin Avenue to the east and the Michigan Meadows Apartment complex across Little Eagle Creek to the south are supplied by IWC.

The nearest body of surface water is Little Eagle Creek located adjacent to the southern property boundary. This creek flows towards the east-southeast and eventually joins to Eagle Creek approximately one mile to the south of the site.

Indianapolis has a temperate climate with warm summers and no dry season. Precipitation is distributed fairly evenly through out the year. The average precipitation is 39.99 inches per year and the average annual temperature is 52.5° Fahrenheit (F). (NOAA, 1989). Over a 29 year period from 1960 to 1989 the average monthly rainfall ranged from a low of 2.69 inches in October to a high of 4.03 inches in June. Average temperature for the same period ranged from a low of 28.0° F in January to a high of 75.8 ° F in July. Spring and early summer rains usually exceed winter precipitation. (Sturm and Gilbert, 1978).

1.1.2 Site History

Two environmental investigations were completed at this property by Engineering Science, Inc. (ESI) in 1992. The initial investigation, entitled *Phase I Information Review Report for General Motors Corporation Allison Gas Turbine Division*, was completed by ESI in July of 1992. This assessment involved no intrusive exploration of environmental conditions. The Phase I assessment identified the following potential areas of environmental concern:

- two reported releases (100 gallons of quench oil in the southwest corner of the property and an unknown amount of hydraulic fluid in the southwest courtyard);
- possible waste burial area at western end of property; and
- possible area of dumping near the northwest corner of the plant.

The above ground storage tanks were reported to be in good condition. The Phase I identified the Plant 10 site as a potential area of concern (PAOC). The report included a recommendation to install three monitoring wells and one soil boring.

An intrusive follow-up assessment of the areas of environmental concern identified during the Phase I assessment was completed by ESI in November of 1993. Methods and results of this additional investigation were reported in a document titled *Phase II Site Assessment Final Report for General Motors Corporation Allison Gas Turbine Division* dated November 19, 1993. During the initial phase of work, three monitoring wells (MW-132, MW-133, and MW-135) were installed and one soil boring (SB-134) was advanced at the site. A soil gas survey was completed on the west side of the property during this investigation. During the second phase of this investigation four monitoring wells (MW-145 through MW-148) were installed and two soil borings (SB-149 and SB-150) were advanced on-site.

Results of this investigation identified trichloroethene (TCE), vinyl chloride (VC), 1,2-dichloroethene (1,2-DCE), tetrachloroethene (PCE), toluene, and methylene chloride in the soil on-site. Compounds most frequently detected included TCE, 1,2-DCE, and VC. The west side of the site was confirmed as a PAOC during the Phase II investigation, however the source was unknown.

O'Brien and Gere Engineers, Inc. (OGE) conducted a Buyer Environmental Assessment for Plant 10 in May, 1994. They advanced six soil borings (SB-10-1 through SB-10-5 and OBG-10-1) and installed one monitoring well MW-10-1 in soil boring OBG-10-1. Surface samples collected included two surface soil samples near an area containing brake pad pieces, two brake pad samples for asbestos testing, two sludge samples from the sumps located south of the building. These sumps have since been removed. A total of six subsurface soil samples and three groundwater samples were also collected.

Fluor Daniel GTI conducted a Remedial Investigation at this site during the period of July 1995 to February 1997. Activities completed during the investigation included the advancement of fourteen soil borings, one Hydropunch, and six Geoprobe borings; collection of soil samples for laboratory analysis; the installation of nine shallow and five deep monitoring wells in the fourteen borings; surveying of all new wells; groundwater elevation monitoring and sampling of all wells on-site; stream survey and sampling of Little Eagle Creek; and rising head permeability tests from the newly installed wells. Results of the investigation were used to better characterize the geology and hydrogeology of the site, to further delineate VOCs and metals occurrence, and to assess the potential risk of VOCs and metals occurrence to human health and the environment.

1.1.3 Nature, Extent and Magnitude of Contamination

Analytical results for soil samples collected from the vadose zone during the above mentioned site investigations indicated the presence of VOCs in 17 of the 23 samples collected. TCE and 1,2-DCE were the most frequently detected compounds. Concentrations of TCE ranged from 29 micrograms per kilogram (ug/kg) to 120,000 ug/kg. 1,2-DCE concentrations ranged from 4 ug/kg to 12,000 ug/kg. Levels of adsorbed VC ranged from 12 ug/kg to 500 ug/kg. TCE was detected on site at one location (MW-132) above the Indiana Department of Environmental Management (IDEM) Tier II Non-Residential Cleanup Goal of 25,730 ug/kg. VC was detected at one location above its Tier II Non-Residential Cleanup Goal of 130 ug/kg. Using the Tier II Non-Residential Cleanup Goals as delineation, VOC occurrence in soil has been defined.

Using TCE as an indicator, multiple source areas (i.e., areas of elevated VOC concentrations) appear to be present in the western portion of the site (e.g., MW-132, GP-2, and MW-133). A soil sample collected from the air-water interface southeast of the plant building (MW10-1) contained 3,800 ug/kg TCE. This value was within the same order of magnitude as two groundwater samples collected from this location, therefore, it is not clear whether a source is present in this area. Levels of TCE an order of magnitude lower were measured in samples collected from the vadose zone on the southeast side of the plant building (MW-152) and further to the south (GP-5). These may represent other small source areas.

One sample collected southeast of the property contained a TCE concentration above the Tier II Residential Cleanup Goal. The sample, collected from a depth of 18-20 feet contained 170 ug/kg TCE which is above the Tier II Residential Cleanup Goal of 80 ug/kg. This sample was however, collected from below the water table. The groundwater sample collected from this location contained 280 ug/l TCE and therefore the soil results may reflect the presence of TCE in the groundwater.

A total of 28 of the 41 groundwater samples collected from monitoring wells during the period of July 1995 to February 1997 contained detectable concentrations of VOCs. Samples from seven of the wells were below detection limits for all analyzed constituents. As was the case with soil, the most frequently detected compounds were TCE and 1,2-DCE. Analytical data indicate detectable TCE concentrations ranged from 5.4 ug/L to 13,000 ug/L, cis-1,2-DCE concentrations ranged from 5.3 ug/L to 65,000 ug/L, trans-1,2-DCE concentrations ranged from 5.9 ug/L to 1,400 ug/L, and detectable VC concentrations ranged from 12 ug/L to 3,400 ug/L. Wells located west, southwest, and southeast of the building and/or property contained TCE, 1,2-DCE, and/or VC concentrations above the Tier II Non-Residential Cleanup goals. Based on this data, VOCs occurrence in groundwater has not been delineated horizontally south and east of MW-157. However, two additional wells are planned for this area. VOCs occurrence in groundwater south of HP-1 near Little Eagle Creek also has not been delineated. Shallow groundwater likely discharges into Little Eagle Creek, and therefore, it is unlikely that dissolved VOCs occurrence extends south of the creek.

Based on isoconcentration maps constructed for TCE, 1,2-DCE, and VC in groundwater, at least two potential source areas of elevated concentrations were identified. These areas are west of the building in the vicinity of MW-132 and southeast of the building in the vicinity of MW10-1. Based on a higher concentration of TCE degradation products (1,2-DCE and VC), it would appear that the potential source area due west of the building is older than the other area. Non-determined aliphatic hydrocarbons were detected in samples collected from MW-157 offsite to the southeast. The occurrence of these compounds appears to be localized in the vicinity of the well.

Groundwater data collected during previous investigations were compared to recent data (July 1995 to February 1997) to evaluate trends in dissolved VOCs concentrations. In general, most of the wells did not exhibit major changes in dissolved VOCs concentrations with time. Dissolved VOCs concentrations did increase in wells MW-132 and MW155. Detected concentrations decreased in wells MW-148, MW-153, and MW-156. Wells MW-132 and MW155 are located in the western potential source area. Well MW-148 is located downgradient of MW-132. MW-153 is located in the well cluster located southwest of the building and MW-156 is located offsite to the southeast.

The discharge (stream flow volume) of Little Eagle Creek was measured on October 4, 1996 and February 10, 1997. Maximum stream flows of 8 cubic feet per second (cfs) and 23.77 cfs were measured for these dates, respectively. Data collected from a gauging station 1.2 miles upstream indicated historical average flows of 11.1 cfs and 30.54 cfs, respectively, for the same two months. This suggests that the gauging station data could be used to describe relative stream flow trends.

Loading of VOCs to Little Eagle Creek was estimated using concentrations in groundwater at HP-1 and the above stream flow data. A concentration of 25 ug/L 1,2-DCE was predicted to be detected in Little Eagle Creek using the October, 1996 flow data. The actual concentration measured in Little Eagle Creek near HP-1 in October, 1996 was 17 ug/L. The predictive model and laboratory analytical results both indicated that detectable TCE and VC concentrations were not present in Little Eagle Creek in October 1996 and February 1997. Both also indicated that detected 1,2-DCE concentrations were not present in February 1997.

1.1.4 Baseline Risk Assessment

Site-specific human health risks were calculated for the site using IDEM and Environmental Protection Agency (EPA) risk assessment methodology. No soil carcinogenic risks for non-residential exposures to soils exceeded the 1x 10^{-5} target risk level. Assessed non-residential scenarios included the on-site worker and on-site construction worker exposure to surface and subsurface soil. The only on-site soil contaminant of interest (COI), vinyl chloride, does not have non-carcinogenic toxicity constants. Therefore, no soil non-carcinogenic hazard indices for non-residential exposures were estimated. On-site soil COI concentrations found do not appear to pose a significant human health threat. No off-site soil COI were identified that required assessment.

Based on the noted exceedances of the Tier II Residential Cleanup Goals at property boundaries and/or at off-site locations, it is apparent that potentially unacceptable risks are posed by potential direct contact (i.e., ingestion) groundwater exposures to off-site residents in the immediate vicinity of the subject site. However, an evaluation of volatilized vapor from groundwater to indoor air using data from an off-site well (MW-157) posed no significant human health threat for offsite residents. No on-site groundwater COI were identified that required assessment.

The surface water non-carcinogenic risks were below the EPA's target hazard index of 1.0. Cis-1,2-dichloroethene, the only surface water COI, does not have carcinogenic toxicity constants. Therefore, no surface water carcinogenic risk levels were estimated. Off-site surface water COI concentrations found do not appear to pose a significant human health threat.

1.1.5 Preliminary Identification of ARARs

For each hazardous waste site governed by CERCLA and SARA, congress has directed EPA to consider the degree of public health or environmental protection afforded by each remedial alternative considered. Section 121(d) of SARA requires that remedial actions be consistent with and in accordance with other environmental laws. These laws may include: the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), the Clean Air Act (CAA), the Toxic Substances Control Act (TSCA), and the Safe Drinking Water Act (SDWA), among other federal laws, and any state law that has stricter requirements than the corresponding federal law.

These regulations and standards preliminarily identified for the **GM-Allison Plant 10** site have been categorized as "applicable or relevant and appropriate requirements" (ARARs), or as "to be considered" (TBCs). ARARs are legally binding. While TBCs are not legally binding, they will be considered along with ARARs as part of the site endangerment assessment and may be used in determining the necessary level of cleanup for protection of health or the environment.

ARARs may be further categorized as: chemical-specific requirements that may define acceptable exposure levels and therefore be used in establishing preliminary remediation goals; location-specific requirements that may set restrictions on activities within specific locations such as floodplains or wetlands; or action-specific requirements that may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous wastes.

Based on these definitions, lists of ARARs and TBCs potentially applicable to the **GM Allison Plant 10** site have been identified and are shown in **Table 1** . This preliminary identification of ARARs and TBCs was used in identifying potential remedial alternatives to be developed and evaluated in the FS. Because the FS is iterative in nature, both state and federal ARAR identification may continue throughout the FS process as additional information concerning remedial action alternatives is acquired. This alternatives array document is intended to solicit any additional ARARs from appropriate state and federal agencies.

2.0 Remediation Cleanup Goals

There are two assumed source areas of COIs at the site; the principal area is located in the western portion of the property and a secondary source area is located in the southeastern corner of the property. Since groundwater flows toward the southeast and the south in the western and southeastern portions of the site, respectively, the most conservative point of regulatory compliance is the southern boundary of the site. The site abuts with the City of Indianapolis property along this southern boundary.

Remediation cleanup goals were determined for groundwater and soil in two phases. The objective of the first phase was to determine the maximum concentration of COIs that could be left in groundwater and not exceed MCLs at the compliance point. The objective of the second phase of modeling was to determine the maximum concentration of COIs that could be left in the soil and, due to leaching, not exceed the groundwater cleanup goals established in the first phase.

2.1 Groundwater Cleanup Goals

2.1.1 Southeastern Area

The southeastern source area, in the vicinity of MW10-1, is located less than 50 feet upgradient of the selected compliance point (the southern property border at the fence line). Little attenuation is expected between the source and the compliance point; therefore, the cleanup goals in this area are set at MCLs. Consequently, groundwater remediation cleanup goals for the southeast source area are 5 ug/L for TCE, 70 ug/L for cis-1,2-DCE, and 2 ug/L for VC.

2.1.2 Western Area

The source area in the western portion of the site is assumed to be represented by MW-132. The nearest compliance point can be conservatively set at the property line located about 180 feet directly south of MW-132, near MW-153. Although not directly downgradient, this location represents the most conservative compliance point for the western area of the site. An alternate compliance point may be set at the creek centerline located about 490 feet directly downgradient of MW-132. The following analysis determined groundwater cleanup goals for each COI at each compliance point using the following methods: (1) a simplified two dimensional (2-D) analytical equation and (2) a three dimensional (3-D) analytical model (AT123D).

The 2-D method used the 1995 chemical data from MW-132 and MW-153. Since this method is sensitive to large variations in concentrations the more rigorous AT123D modeling was completed to better deal with the observed variability in chemical data (as suggested by the most recent 1997 results). As shown in the next two sections, both methods do yield similar results when considering chemical data through 1995. However, if the latest 1997 data is used, the simplified 2-D analytical equation would yield a different cleanup goal. Consequently, the results of the 3-D analysis are used to calculate site cleanup goals.

2.1.2.1 Simplified 2-D Analytical Equation

If volatilization to the vadose zone and biodegradation are neglected, the principal mechanism for the attenuation of COI concentrations in groundwater is hydrodynamic dispersion. The equation describing COI dispersion from a point source located at the origin in a two-dimensional aquifer subject to uniform flow is (Bear 1979, eq. 7-156):

$$dC(x,y,t) = \frac{dM}{2\pi[2D_L't]^{1/2}[2D_T't]^{1/2}} exp\left[-\frac{(x - v't)^2}{4D_L't} - \frac{y^2}{4D_T't}\right] \tag{1}$$

Where

dM	=	C_o Q dt (mass of instantaneous slug of tracer)
v'	=	v/R
D_L'	=	D_L/R
D_T'	=	D_T/R
Co	=	input COI concentration
C	=	downgradient COI concentration
D_L	=	coefficient of longitudinal dispersivity
D_T	=	coefficient of transverse dispersivity
M	=	COI mass
Q	=	input COI flow
R	=	retardation coefficient
t	=	time
v	=	velocity of groundwater flow
x	=	longitudinal (i.e., along the direction of flow) coordinate
y	=	transverse coordinate

Convolution and integration of this equation can be used to obtain analytical expressions for the downgradient COI concentration that spreads from a given source area and input concentrations. Analytical codes such as AT123D (Yeh, 1981), provide solutions for the dispersion/retardation problem. It is important to note that the general dispersion equation, and particular solutions such as above, are linear with respect to the associated COI concentrations. Therefore, if the input concentration is halved and all other input parameters are fixed, all the calculated downgradient concentrations also will be halved.

In addition to the theoretical framework presented above, steady-state COI distributions were hypothesized in the development of the cleanup objectives for the groundwater at the site. The facility has apparently been operated only as a warehouse since 1973. Therefore, it can be assumed that on-site operations involving the use of chlorinated solvents have ceased for 20 or more years. A rough calculation of COI migration in the western area based on the approximate distance from well MW-132 to the point of compliance (set at MW-153) indicates the three COIs have most likely reached a steady-state condition at MW-153 in a time frame of less than 20 years. Additionally, comparisons of groundwater data collected from 1992 to 1995 reveal generally consistent concentrations of the groundwater COI. These two lines of evidence support the hypothesis that the COI plumes have likely reached steady-state conditions from well MW-132 to MW-153.

Given that the downgradient analytical data for well MW-153 is available and that the concentration distributions have likely reached steady-state conditions, the cleanup criteria using the linear relationship between source area COI concentrations and point-of-compliance COI concentrations can be expressed as:

$$C_{goal} = (C_{point\ of\ compliance})\ (C_{MW132}/C_{MW153}) \qquad (2)$$

where:

$C_{point\ of\ compliance}$ is represented by the MCL for each COI.

Using equation (2) and the analytical results from 1995, the calculated concentration cleanup goals for the western area are:

C = 5(1,700/570) = 15 ug/L for TCE,
C = 70(5,115/980) = 365 ug/L for 1,2-DCE, and
C = 2(600/22) = 55 ug/L for VC.

Note that 1,2-DCE and VC are degradation products of TCE and more volatile than TCE. TCE has a half-life of one year in soil and 4.5 years in groundwater, however half-life in groundwater may be reduced to one year in the presence of aerobic bacteria (Howard, et al., 1991). Therefore, the treatment of TCE to a cleanup goal of 15 ug/L will result in depletion of the biodegradation parent product (TCE) and in the enhanced volatilization of 1,2-DCE and VC. Because of these two factors and because the cleanup goal for TCE is more stringent than that for 1,2-DCE or VC, the actual final concentrations of 1,2-DCE and VC are expected to be significantly lower than the cleanup goals presented above, when the cleanup goal for TCE is achieved.

2.1.2.2 3-D Analytical Model (AT123D)

The analytical groundwater flow and solute transport model AT123D was used as a second, more rigorous, method to determine groundwater cleanup goals in the western area. The simplifying assumptions associated with this groundwater flow model requires the aquifer to be treated as homogenous and isotropic with infinite or user-defined limits on areal extent. Groundwater flow is assumed to be uniform and at steady-state conditions. These assumptions were reasonably satisfied by available site hydrogeologic information. The following model input parameters, taken from qualified field data wherever possible, were used for the base-case model.

AT123D Model Input Values			
Aquifer Properties			
	Value	Units	Reference
thickness	18	feet	well logs
soil bulk density	1.76	g/cm³	lab results
effective porosity	25	percent	assumed, Dominico and Schwartz, 1990.
hydraulic conductivity	137	ft/d	slug tests
hydraulic gradient	0.0045	ft/ft	water level data
plume travel distance	460	ft	chemical data
longitudinal dispersivity	46	ft	10% of travel distance (Gelhar et al., 1992)
transverse dispersivity	4.6	ft	1% of travel distance (Gelhar et al., 1992)
vertical dispersivity	0.16	ft	0.035% of travel distance (Gelhar et al., 1992)
total organic carbon	0.0012	mg/kg	lab results

Chemical Properties					
	TCE	cis-1,2-DCE	VC	Units	Reference
distribution coefficient	1.5E-4	5.9E-5	5.9E-5	m^3/kg	USEPA, 1990
biodegradation half-life	4.5	7.9	7.9	years	Howard et al., 1991
source loading rate	1E-4	1E-4	1E-4	kg/hr	estimated using site data

The calibration of the model presented a number of challenges. First, the data used to calibrate the model was obtained from wells completed either in the upper or lower portion of a relatively thin aquifer. However, data from these wells indicate a vertical concentration gradient exists. Second, for calibration, the available chemical record is limited as it contains wells that were sampled only two to four times in the period from 1992 to 1997. Finally, the recent variability in concentrations is relatively large in MW-132 and MW-153. Based on these observations, model calibration targets were established as follows: (1) the chemical record from 1992 to 1995 was used, (2) wells were designated "shallow" or "deep" if completed in the upper or lower half of the aquifer, respectively, and (3) modeled concentrations should be within the observed variability of data from 1992 to 1995 or within the same order-of-magnitude.

TCE was used to calibrate the model using the above base case values. This provided a starting point from which source area loading and dispersivity values were adjusted until a reasonable match between predicted and observed TCE groundwater concentrations was achieved. The time of release is not known but was assumed to be 1973 and, therefore, the calibration period is from 1973 to 1993.

To achieve an acceptable match between predicted and observed TCE concentrations, the source loading was increased from the initial estimate of 1.4E-4 kg/hr to 2.5E-4 kg/hr and the values for transverse and vertical dispersivity were subsequently reduced from 4.6 to 3.3 feet and from 0.16 to 0.033 feet, respectively. The following is a summary of the calibration results for TCE in ug/L using the chemical data record from 1992 to 1995.

Location	TCE Concentrations (ug/L)					Comments
	Observed				Predicted	
	1992	1993	1995	1997	1993	
MW-132	280	1900	1700	15000	790	Source Area - Shallow
MW-147	-	39	<5	51	5	Source Area - Deep
MW-133	47	24	23	53	93	Shallow
MW-145	-	9	5.6	43	20	Deep
MW-153	-	-	570	5.4	150	Shallow

To check the calibration, the calibrated model was used to simulate cis-1,2-DCE from 1973 to 1993. The only parameter that can be adjusted is the source area loading rate, once chemical-specific properties are changed. The results are shown in the table below.

Location	cis-1,2-DCE Concentrations (ug/L)					Comments
	Observed				Predicted	
	1992	1993	1995	1997	1993	
MW-132	1500	2400	5100	65000	5200	Source Area - Shallow
MW-147	-	<140	<5	95	61	Source Area - Deep
MW-133	81	56	70	100	862	Shallow
MW-145	-	440	530	<5	135	Deep
MW-153	-	-	980	<5	1220	Shallow

Based on the calibration results, the model is deemed capable of being used as a tool to determine groundwater cleanup goals for TCE, cis-1,2-DCE, and VC. Using the calibrated model, source loading rates were adjusted for each chemical until concentrations at the compliance points were at or below their respective MCL. The on-site cleanup levels for the conservative compliance point at the property line are 9 ug/L for TCE, 100 ug/L for cis-1,2-DCE, and 3 ug/L for VC. For the other possible compliance point at the stream, the cleanup goals are 15 ug/L for TCE, 170 ug/L for cis-1,2-DCE, and 5 ug/L for VC.

2.2 Soil Cleanup Goals

The objective of the second phase of modeling was to determine the maximum concentration of COIs that could be left in the soil without leaching to groundwater and exceeding the groundwater cleanup goals established in the phase one analysis. The 1-D analytical vadose zone model SESOIL (GSC, 1996) was used with a climatic database for Indianapolis to predict groundwater concentrations due to leaching of COIs from the vadose zone. Infiltration is the driving force for downward migration of COIs from the vadose zone.

The simplifying assumptions associated with SESOIL requires the soil to be treated as homogenous and isotropic with user-defined limits on source areal extent. These assumptions were reasonably satisfied by available site hydrogeologic information. The following model input parameters, taken from qualified field data wherever possible, were used in the model.

SESOIL Model Input Values					
Soil Properties					
	Value	Units	Source		
thickness	10	feet	well logs		
soil bulk density	1.76	g/cm^3	lab results		
effective porosity	25	percent	assumed, Dominico and Schwartz, 1990.		
total organic carbon	0.0012	mg/kg	lab results		
intrinsic permeability	1.0E-8	cm^2	assumed, GSC, 1996		
Chemical Properties					
	TCE	cis-1,2-DCE	VC	Units	Reference
molecular weight	131.50	96.94	62.5	g/mol	GSC, 1996
solubility	1100	3500	2670	mg/L	GSC, 1996
Henry's Constant	0.0103	0.00674	0.00674	m^3-atm/mol	GSC, 1996
K_{oc}	126	49	57	-	GSC, 1996
diffusion coefficient in air	0.083	0.091	0.091	cm^2	GSC, 1996 GSC, 1996

In the model, the source was assumed to occupy the upper five feet of the vadose zone. The initial soil concentration for each COI was loaded into this zone during the first model time step. As a staring point, the IDEM Tier II Non-residential Cleanup Goals were used. The simulation period was ten years with the greatest leachate concentration, typically occurring within the first five years, applied to the groundwater. The Summer's Method (GSC, 1996) was used to estimate the groundwater concentration due to leaching from the vadose zone. The leachate was assumed to enter at the water table over a 30-square foot area and mix completely with clean groundwater in the upper half (9 feet) of the aquifer.

The resulting groundwater concentration due to leaching was compared to the groundwater cleanup goals determined using the AT123D model. The maximum soil concentration for each COI that leached to produce a groundwater concentration equal to the groundwater cleanup goal was determined. The modeling results are presented below.

Site Specific Soil Cleanup Goals (ug/Kg)			
Southeastern Area			
	TCE	**cis-1,2-DCE**	**VC**
	24,182	181,425	4,417
Western Area			
	TCE	**cis-1,2-DCE**	**VC**
Property Line Compliance Point	43,528	259,179	6,625
Little Eagle Creek Compliance Point	75,547	440,605	10,042

IDEM Tier II Nonresidential cleanup goals for subsurface soil are based on (1) direct-contact exposure scenarios using standard human health risk assessment calculations and (2) protection of groundwater (IDEM, 1996). The site specific subsurface soil cleanup goals presented in the above table were based on protection of groundwater. These cleanup goals were compared to the Tier II goals for direct-contact. The calculated site specific closure goals are below the Tier II goals for direct-contact exposure scenarios for TCE and cis-1,2-DCE. However, the site specific goal for VC is above the Tier II value; therefore, to be protective of human health, the Tier II value of 300 ug/kg for VC in subsurface soils (IDEM, 1996) is used.

3.0 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

3.1 Introduction

The objective of the development and screening of technologies is to identify, screen, and develop alternatives for removal, containment, treatment and/or other remediation of impacted areas at the site. The initial development and screening of alternatives is based on information provided in the Remedial Investigation Report.

COIs, impacted media, extent and magnitude of occurrence, and cleanup goals are discussed in Section 1.0. In summary, the COIs are TCE, 1,2 DCE, and VC. Two general areas of concern requiring remedial evaluation were identified, one southeast of the warehouse building near MW10-1 and a second comprising the western portion of the site south of MW-132. Remedial alternatives need to be considered for COI occurrence in groundwater in the shallow unconfined aquifer in both areas of concern. Alternatives for the remediation of COI in soil only need to be considered for the western area of concern. Initial screening for remedial technologies was accomplished by using matrices for evaluating remediation strategies **(Tables 2 and 3)**. These matrices are based on applicability (technical feasibility), protection of public health and the environment, cost and treatment time, and administrative considerations. The development and screening criteria are discussed in more detail below.

3.1.1 Overview of Development and Screening Process and Criteria

In order to screen remediation technologies and identify potential corrective measure alternatives, the following site specific information is considered:

- chemical type and characteristics;
- site medium;
- chemical concentrations distribution throughout medium;
- cleanup goals;
- technical feasibility of attaining cleanup goals;
- time frame for remediation and;
- costs to accomplish the remedial objective.

3.1.1.1 Applicability

The applicability of a technology to remediate impacted areas at any specific site is evaluated with regard to the specific advantages and disadvantages listed below.

<u>Advantages</u>

- ☐ Mobility reduction: when the technology significantly reduces the potential for migration.

- Destruction: when the technology destroys, degrades or otherwise transforms the chemical to a non-toxic form.

- Volume reduction: when the technology significantly reduces the amount of contamination in the impacted areas.

- Performance and reliability: whether the technology has a proven track record for treating the chemicals in a similar site setting.

- Implement ability: when the logistics of designing, procurement, installing, and operating the technology at the given site appear to be direct.

<u>Disadvantages</u>

- Emerging technology: when a technology is not fully developed and may not be reliable.

- Inappropriate technology: when site conditions are not technically suitable for the application of the technology.

- Not permittable: if permitting of the technology at the site is very difficult or impossible to obtain.

- Additional treatment required: if the technology requires additional equipment or processes to handle secondary controls (e.g., off-gas treatment)

- Operating area: application of the technology would require a large area of the site surface.

- Inappropriate soil material: if the soil structure is incompatible with the treatment process.

- Depth to water: whether depth to groundwater is inappropriate for the treatment alternative.

- Potential additional liability: whether the treatment technology may add additional liability.

The advantages and disadvantages are used to give each alternative a numeric applicability rating. This rating gives a numerical value to the relative applicability of the technology to the specific site with regard to technical merits and the ability to permit the process. This is a subjective rating based upon the listed advantages and disadvantages of the technology applicability as well as any additional professional judgements. The rating scale is from zero to five, with zero equal to "not applicable, available, or implementable" to five for "widely used, proven and applicable."

3.1.1.2 Protection of Public Health and the Environment

Any remediation technology under consideration should maintain exposure to site workers, visitors, and surrounding population to a minimum. The treatment technology is considered an advantage when the technology reduces human exposure to the chemicals or minimizes the exposure through the process of remediation. This is a numerical score ranging from zero to three based on the use of the technology. Community impact is also important and the technology is considered a disadvantage if the application of the technology could be perceived as negatively impacting the local community or environment.

3.1.1.3 Costs and Treatment Time

This rating gives a numerical value to the relative capital and operating costs incurred in implementing the technology.

- Capital Costs: relative cost of obtaining and installing the technology.

- Operating Costs: relative costs of operating and maintaining the treatment system.

The treatment time rating gives a numerical value to the potential of the treatment technology to perform the desired site remediation within an acceptable time.

3.1.1.4 Administrative Considerations

These considerations include the time necessary for administrative project oversight and control from initial conception through cleanup. This rating gives a numerical value to the relative administrative oversight required by the technology. Ratings are from one to three with three requiring the least amount of administrative oversight. This includes required engineering design work and oversite.

3.1.1.5 Rating Score

The rating score is defined as the arithmetic scoring of each of these criteria based on the following calculation:

Rating Summation = AP x HE x AC x (C + T)

Where	AP	=	Applicability
	HE	=	Health and the Environment
	AC	=	Administrative Considerations
	C	=	Costs
	T	=	Treatment Time

For each technology, these criteria are given a score that ranges from one up to three or five, depending on the criteria. Table 2 provides a detailed summary of the scoring used within each criteria.

3.2 Development of Alternatives

Remediation alternatives considered for this site fall under two areas of classification. The first is non-treatment of impacted soil and groundwater and the second is active soil and groundwater treatment. Each of these categories is broken into subsections with alternative technologies relevant to that process. The alternatives are presented in matrix form with scoring as presented on **Tables 2 and 3**. The alternatives initially scored and presented are under general consideration and may be applicable to this site. The alternatives are broken down as follows:

3.2.1 Non-Treatment of Impacted Soil and Groundwater

Listed below are options that provide a baseline by which to compare other alternatives. Alternatives are as follows:

NO ACTION
- Leave existing levels in place with long term monitoring

CONTAINMENT
- Groundwater Extraction and Treatment
- Air Sparge Curtain

3.2.2 Active Soil and Groundwater Treatment

Provided below are active remediation alternatives to address either the soil or groundwater. Alternatives are as follows:

VOLATILIZATION
- Soil venting only
- Soil venting with groundwater extraction
- Soil venting with air sparging

EXCAVATION
- Soil removal and disposal

EXTRACTION
- Groundwater pumping

DEGRADATION
- Ozone injection

3.3 Screening of Alternatives

3.3.1 Non-Treatment of Impacted Soil and Groundwater

3.3.1.1 Description

The no action alternative will require long-term groundwater gauging and/or sampling on a periodic basis (possibly quarterly) to track the movement of the COIs. Deed restrictions will be required for the site that prohibit the installation of an on-site water supply well and excavation activities in the western portion of the site. The site will also have to remain zoned for commercial/industrial use. Institutional controls restricting the installation of water supply wells off-site to the southeast and south would also be required. Use of this alternative also assumes the COIs will naturally attenuate through biodegradation and dispersion.

Containment technologies, such as groundwater interceptor wells or an air sparge curtain, also may place a restriction on the land. The purpose of the containment technologies is to intercept the COIs before they migrate off-site in the groundwater. Typically, a line of extraction wells or air sparge wells is placed along the downgradient property line. Groundwater is either pumped from the aquifer and treated (extraction) or stripped of the COI in place (air sparge). On-site deed and zoning restrictions would be similar to the no action approach. The sale of the land may be restricted after a containment technology is implemented stating the technology may not be removed and must continue to be maintained.

3.3.1.2 Screening

3.3.1.2.1 Applicability

The no action and containment treatment options were considered not applicable (AP 0-2). These alternatives do not reduce the mobility, destroy, or reduce the volume of contaminants. It is unlikely that the City of Indianapolis (property to south) or residents to the southeast would be willing to deed-restrict their properties.

3.3.1.2.2 Protection of Public Health and the Environment

These alternatives are not in the best interest of the public health or the environment in this situation (HE 1-2). The assessment to determine the horizontal and vertical extent of impact indicated possible impact to the Little Eagle Creek, although risk assessment determined no unacceptable risks.. Additionally, monitoring wells located off-site to the southeast of the property indicated levels above federal MCLs. Due to the possibility that a water supply well could be installed off-site, this course of action is not recommended.

Discussions with Marion County Health Department personnel indicated that there are no ordinances prohibiting the installation of a water supply well on private property in Indianapolis. However, Section 18-803 of the County Health Code states that the Health Department can prohibit the installation of water supply wells in areas where groundwater has been determined to be contaminated by chemical, biological, or radiological contaminants. Sherry Winters, Field Supervisor, indicated, however, that if "chemical contamination" were detected in a newly installed well, they could ask the owner to connect to public water supply if it were available (within 100 feet). However, since the water supplier is a private company they could not automatically make someone use the water supply.

3.3.1.2.3 Cost

The costs for continued monitoring are minimal on an annual basis, but can be substantial in the long term due to perpetual monitoring requirements.

Containment controls would cover the horizontal extent both on the southern and eastern property lines. Capital, installation, and one year of operation and maintenance costs could range from $200,000 to $400,000 for groundwater extraction and treatment and $100,000 to $300,000 for an air sparge curtain. The concentrations of chlorinated solvents in the groundwater may also require the use of an air stripper before carbon polishing in the groundwater extraction and treatment option.

3.3.1.2.4 Administrative considerations

These technologies were considered to require normal or no administrative oversight (AC 2-3). The following administrative controls were identified:

Continued monitoring:

- quarterly or periodic reporting (to client and regulatory agency)
- sampling/purge water drum disposal or permit to discharge

Institutional actions:

- possible public hearings
- continued communication with regulatory agency providing necessary documentation for re-zoning or deed restriction as required by agency

Containment:

- water discharge permitting either storm or local sanitary sewer
- quarterly or periodic reporting (to client and regulatory agency)
- site safety plan
- engineering wells, equipment, and piping design
- engineering operation and maintenance manual

3.3.1.2.5 Treatment Time

The technologies were considered to have treatment times either longer than desired or acceptable (AC 1-2), for no action and containment, respectively.

3.3.2 Active Soil and Groundwater Treatment

Active soil and groundwater treatment can be accomplished by several methods including soil venting, soil venting combined with air sparging, soil venting combined with groundwater extraction, soil excavation and disposal, groundwater pumping alone, and contaminant degradation. These options are discussed in the following sections.

3.3.2.1 Description

Volatilization is the process of removing the contamination from the saturated or unsaturated zone via the vapor phase. Volatilization of adsorbed phase contaminants in the unsaturated zone typically involves soil ventilation. Soil venting (soil vapor extraction) removes VOCs from vadose zone soils by inducing air flow through the impacted areas. Venting is typically performed by applying a vacuum to vertical vapor extraction wells screened through the level of soil contamination using a vacuum blower. The resulting pressure gradient causes the soil gas to migrate through the soil pores toward the vapor extraction wells. VOCs are volatilized out of the subsurface and converged to the surface by the migrating soil gas.

A process that volatilizes both adsorbed phase contaminants in the saturated and unsaturated zones and dissolved phase contaminants in the saturated zone is air sparging with soil venting. Air is forced under low pressure through a 1 to 2 foot section of well screen into the saturated zone generally at a point 5 to 20 feet below the vertical extent of impact. Sparging creates air-filled porosity in the saturated zone which facilitates direct volatilization of contaminants from saturated soil and removes VOCs from groundwater. The turbulence created by sparging improves mixing in the saturated zone which increases the transport of contaminants from saturated soils to groundwater.

A less-often used technology is vertical circulation wells that extract groundwater at the well bottom, air-strip within the well to remove VOCs, and finally discharge the treated groundwater through the top of the well at the water table. This is also known as "in-well sparging" technology. Several methods can be used to induce vertical flow within the well and thereby create the circulation cell within the aquifer in the vicinity of the well. Vapors generated within the well are removed, treated, and discharged.

Vertical circulation wells are not appropriate because, as an emerging technology, it is not widely used and does not have a proven track record. Furthermore, this technology is essentially a groundwater pump, treat, and reinject system without the use of submersible pumps or air stripper. As with conventional pump-and-treat systems, groundwater cleanup times and their effectiveness are diffusion-limited resulting in ineffective and long clean-up times.

Excavation involves removing soil from the impacted area using heavy machinery. The horizontal and vertical extent of impact is first identified. Heavy machinery is then used to remove the impacted soil while pumps extract the exposed groundwater. The soil is typically placed directly in the back of a staged truck while the groundwater is treated via activated carbon and discharged. The excavated soil is taken to off-site facilities and treated. The excavated soil is replaced with clean backfill. The on-site remediation of the soil requires equipment capable of processing several thousand cubic yards of soil and is not feasible for this site.

Extraction of groundwater is historically the most common remedial technology addressing dissolved phase contaminants. This technology employs either surface mounted or downwell pumps. Recovery wells are placed either within the impacted groundwater or perpendicular to the groundwater gradient at the leading edge of impacted groundwater. Downwell pumps extract the groundwater and convey it to an on-site treatment facility. This technology addresses only groundwater contamination. Vadose zone soils are not remediated.

Advanced oxidation processes degrade aqueous contaminants by reaction with hydroxyl radicals. The hydroxyl radicals are typically produced using ozone and/or hydrogen peroxide. Ozone is a highly reactive form of oxygen which reacts preferentially with organic compounds containing a double bond structure (unsaturated). Compounds with this double bond structure include chlorinated solvents. Ozone is injected into the aquifer at or below the vertical extent of contamination using an ozone generator.

3.3.2.2 Screening

3.3.2.2.1 Applicability

Of the alternatives evaluated, the only two that are the most applicable are soil venting with groundwater extraction and soil venting with air sparging (AP 5, see Table 2)). Excavation is not considered feasible (AP 2) due to the value of soil requiring removal, treatment, and disposal near MW-132 and SB-150 (approximately 250 cubic yards). Also, the more favorable technologies are able to remediate the soil as part of their overall operation. Groundwater pumping alone is also feasible (AP 3) and could place control on the movement of groundwater, but it will not address the impacted soil which would continue to contribute to the groundwater contamination. Like groundwater extraction, soil venting only (AP 2) will address only one phase of the contamination; the adsorbed phase chemicals in the unsaturated zones.

3.3.2.2.2 Protection of public health and the environment

The in-situ treatment technologies that are most feasible in this situation are inherently more protective of human health (HE 3) than ex-situ technologies such as excavation (HE 2). Excavation would require the use of heavy machinery and often leads to the uncontrolled release of dust and vapors from the excavations. The water and air discharge from an in-situ technology are regulated by state agencies to protect the public health and the surrounding environment.

3.3.2.2.3 Cost

A volatilization technology requires the installation of wells, trenching, and an operating system after completing a full design. Capital, installation, and one year of operation and maintenance costs for a volatilization system range from $100,000 to $300,000 with soil venting only as the least expensive. Soil venting with groundwater removal or air sparging are more expensive technologies.

A groundwater-only pumping system is less expensive than volatilization with a range of $100,000 to $300,000 for capital, installation, and one year of operation and maintenance. However, these systems often require significantly longer periods of operation than more aggressive treatments such as soil venting and air sparging and have higher overall annual operation and maintenance costs.

Excavation and disposal of impacted soils above cleanup goals cost ranges from $100,000.00 to $300,000.00. However, soil excavation alone does not address current groundwater impacts.

The costs for installing and operating an ozone injection system is expected to be greater than $500,000 for capital, installation, and one year of operation and maintenance.

Any system removing groundwater will most likely require the use of either an aqueous phase granular activated carbon (GAC) treatment or other technology prior to discharge to meet effluent standards. An alternative to GAC for groundwater treatment is an air stripper, however, these units require significant additional maintenance and there is a potential for more frequent discharge excursions. Groundwater removal may also require the use of an air stripper prior to carbon polishing based on some of the concentrations of chlorinated compounds in the groundwater.

3.3.2.2.4 Administrative considerations

Each alternative scored the same regarding administrative considerations (AC 2). Any system requiring the removal of soil vapors or groundwater will require discharge permitting, mass removal tracking, monthly or quarterly reports, engineering design and equipment sizing. Excavation will require classification permitting and disposal permitting along with typical excavation reports. Ozone injection may require special permitting but it is highly reactive and has a limited life in the usable form. Extra site safety controls would be necessary, however, for on-site personnel performing operation and maintenance tasks within the remediation treatment facility

4.0 TREATABILITY INVESTIGATIONS

4.1 Introduction

Treatability investigations are used to determine the feasibility of a proposed remedy and to provide data for remedial design purposes. A review of historical site data indicates no treatability investigations have been conducted at this site.

4.2 Pilot Scale Test

Based on the screening of technologies and the potential applicability of air sparging with soil venting , Fluor Daniel GTI conducted a pilot scale test using this technology. On February 24, 1997, a soil venting (SV), air sparge (AS), and combined AS/SV pilot test was conducted in the southeastern portion of the site. The objectives of the pilot testing were as follows.

- evaluate the technical feasibility of using the AS/SV technology at the site
- determine the radius of influence for single-well SV test
- determine the radius of influence for single-well AS test
- estimate flow rates and VOC emission rate during a combined AS/SV test

The nested well SP1 was used for the pilot tests. The well is constructed of a 1-inch diameter PVC sparge point screened from 23 to 25 feet below ground (bg) and a 4-inch diameter PVC vent well screened from 5 to 15 feet bg. The three 2-inch diameter PVC observation wells OB-1, OB-2, and MW-10 were used, they are located 5, 10 and 20 feet from SP1, respectively. OB-1 is screened from 5 to 15 feet bg, OB-2 from 5 to 15 feet bg, and MW-10 from 7 to 17 feet bg.

4.2.1 Soil Vent Pilot Test Methods and Results

The first test conducted was a step-vacuum soil vent test using a 1.0 Hp Rotron regenerative blower to apply a vacuum to SP1 at settings of 7, 14, and 21 inches of water. The steps were conducted for 30, 15, and 15 minutes, respectively. Corresponding air flow rates, measured at the wellhead using a differential flow sensor, were 63, 88 and 137 scfm, respectively. Vapor concentrations in the effluent were 1.2 ppmv and 4.0 ppmv for the first step and third step, respectively.

The pretest depth to water was 13.50 feet below the top of casing. The well is screened from 7 to 17 feet below grade and has about a 3-foot stickup yielding an available screen interval of 3.5 feet. Observation well vacuum is summarized in **Table 4**. **Figure 4** shows a plot of vacuum versus distance for each vacuum setting with linear and logarithmic scales presented in the upper and lower plots, respectively.

The vacuum radius of influence (ROI) is defined as the distance at which subsurface vacuum equals 0.1 inches of water. The ROI is calculated at 25, 28, and 29 feet for vacuum settings of 7, 14, and 21 inches of water, respectively. A design flow rate of 88 scfm per extraction well (25 scfm per foot of screen) at a vacuum of 14 inches of water will produce an ROI of 28 feet.

Short-term SV tests were conducted in wells MW-132, MW-153, and MW-154. Only about one foot of screen was exposed at MW-132 which was insufficient to conduct a test due to upwelling of the water table. At 45 inches of water, a flow rate of 88 scfm was recorded at MW-153. The available screen interval was about 3.5 feet which yields 25 scfm per foot of well screen. An air sample collected after ten minutes was non-detect for VOCs. At 65 inches of water, no measurable flow was observed in MW-154. The available screen was 8 feet. These results suggest that adequate air flow rates can be achieved at most locations across the site except in the extreme northwest portion due to greater amounts of clay and silt in the vadose zone.

4.2.2 Air Sparge Pilot Test Method and Results

The second test was an air sparge test conducted on the SP1 sparge point. Using a portable compressor, an air flow of 9.5 standard cubic feet per minute (scfm) at a pressure of 4.8 pounds per square inch (psi) was applied to SP1. During the sparge test, depth to water, dissolved oxygen, and pressure measurements were recorded at OB-1, OB-2, and MW-10. The test data is summarized in **Table 5**. The results for dissolved oxygen, pressure, and upwelling (change in depth to water from static) are illustrated in **Figure 5** for each parameter versus time and distance.

Dissolved oxygen concentrations increased within 10 minutes in OB-1 and OB-2. There was a delay of about 40 minutes before an increase was observed in MW-10. Dissolved oxygen concentrations stabilized in all observation wells within 60 minutes. Dissolved oxygen increased above pretest levels by 2.5 mg/L in OB-1, 3 mg/L in OB-2, and 2 mg/L in MW-10.

Air pressure in the unsaturated zone increased throughout the test in OB-1 and OB-2, observed pressures in MW-10 initially increased but appeared stable throughout the test. At 52 minutes, pressures were 0.22 inches of water in OB-1, 0.09 inches of water in OB-2, and 0.075 inches of water in MW-10.

Depth to water was measured to record any increase in the water table elevation. During the early stages of injecting air below the water table, the water table rises (upwells) in the vicinity of the sparge well. As preferential air channels develop, the upwelled area collapses and begins to return to static or near-static levels. Maximum upwelling was recorded at 37 minutes with 0.75 feet in OB-1, 0.97 feet in OB-2, and 0.44 feet in MW-10. Within 65 minutes, the upwelled area collapsed to 0.3 feet in OB-1, 0.42 feet in OB-2, and 0.21 feet in MW-10. Upwelling was greater at a radial distance of 10 feet from SP1 in OB-2 than at OB-1 which is located at 5 feet. This may indicate preferential flow in the direction of OB-2 due to heterogeneities in aquifer materials.

Dissolved oxygen is the primary indicator of sparging ROI with pressure and upwelling providing qualitative indications of ROI. Analysis of these parameters indicates an ROI of 20 feet is possible at an air flow rate of 9.5 scfm at 4.5 psi.

4.2.3 Combined AS/SV Test

After about 60 minutes of continuous air sparging, the vapor extraction blower was activated to conduct the combined AS/SV test. Concentrations in vapors from SP-1 after approximately 30 minutes of the combined test were 10 ppmv based on FID readings. An air sample was also collected in a Tedlar bag and sent for analysis of VOCs using EPA Method TO-14. VOC emission rates could not be evaluated because analytical results were non-detect for all analytes. Possible reasons for not detecting VOC vapors in the effluent include: (1) VOC concentrations in soil in the southeastern area are relatively low, (2) a longer test may have been needed, or (3) leakage around the test well may diluted the effluent air stream. Regardless, the primary goal of the test was to investigate the applicability of AS/SV at the site. The pilot test results demonstrate that this is a viable technology given the site hydrogeologic conditions.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

5.1 Introduction

The previous section identified and screened potential technological alternatives and provided two viable options for site remediation. The objective of the following detailed analysis of alternatives is to describe in detail and rank, the two options.

5.1.1 Overview of Detailed Analysis and Criteria

The two corrective measure alternatives identified in the previous section are evaluated and ranked for their suitability in remediating soil and groundwater at the site. The basic mechanism for the screening process is a subjective rating system where each feasible technology is compared on a relative basis with regard to the site conditions and the following considerations:

- Applicability;
- Protection of public health and the environment;
- Cost; and
- Administrative considerations.

5.2 Individual Analysis of Alternatives

5.2.1 Soil Venting with Groundwater Extraction

5.2.1.1 Description

Soil venting with groundwater extraction simultaneously removes fluids and vapors from either a single extraction well or separate venting and groundwater pumping wells thereby addressing both the saturated and unsaturated zones. The SVE removes VOCs from the unsaturated zone by inducing air flow through contaminated areas. Soil vapor extraction is typically performed by applying a vacuum to vapor extraction wells screened through the level of adsorbed phase contamination. The resulting vacuum gradient causes the soil gas to migrate through the soil toward the vapor extraction wells. VOCs are volatilized by the passing air and conveyed to the subsurface by the migrating soil gas.

Groundwater extraction is accomplished by use of either a single submersible electric pump or pneumatic suction pump at the surface, using a variety of equipment. Soil vapors can be recovered from the pumping wells. However, based on known site conditions, separate groundwater pumping and vapor extraction wells are needed. This is because a greater number of VES wells are required compared to groundwater wells. Recovered groundwater is treated via air stripping or liquid phase granular activated carbon (GAC). Air stripping involves the physical removal of a VOC from the water stream. This is accomplished by cascading the water stream over a counter-current stream of air. Packing material in the stripper provides additional surface area to improve the removal process. Air stripping is a preferred technology when the groundwater pumping rate and dissolved VOC concentrations are relatively high and dissolved metals concentrations are relatively low. Iron fouling due to oxidation can become a maintenance issue.

Liquid-phase GAC adsorption is the accumulation of a chemical from a liquid phase onto the surface of the carbon. The adsorptive properties of GAC are due mainly to its highly porous structure and resulting large surface area. Contaminated water is generally treated by passing it through two vessels containing GAC arranged in series. The first vessel acts as the primary treatment unit and the second acts as a polishing treatment unit. When the primary vessel becomes saturated, it is removed and is replaced with the secondary vessel. A fresh carbon drum is placed in the secondary position. This process is repeated when the primary vessel reaches saturation. Liquid phase carbon adsorption is the preferred water treatment technology when dissolved VOC concentrations and groundwater pumping rate are relatively low.

5.2.1.2 Soil Venting with Groundwater Extraction Criteria

5.2.1.2.1 Applicability

Groundwater extraction with soil venting could be implemented in both areas of concern. Groundwater extraction would be used to treat dissolved VOCs in both areas. Soil venting would be used to treat VOCs in soil in the western area only. Groundwater extraction and treatment is a widely used technology for the treatment of VOCs in groundwater in hydrogeologic settings similar to the site. Groundwater pumped form the subsurface is treated and discharged to a publicly owned treatment works (POTW) or to the surface with appropriate permitting. The water stream is typically treated using air stripping or liquid phase GAC. Based on assumed pumping rates and potential VOC concentrations, the air stripping technology would likely be employed. Soil venting is a widely used technology to address VOC occurrence in soil. Based on the VOC recovery rates, off-gas treatment of the emissions may or may not be required.

5.2.1.2.2 Protection of Public Health and the Environment

Since this technology extracts volatilized vapors, it may require an off-gas treatment technology such as vapor phase carbon adsorption to prevent migration of the vapor plume into the residential areas. Since this technology also extracts groundwater, treatment prior to discharge will be required.

5.2.1.2.3 Cost

The number of extraction wells depends on the groundwater capture radius for each well. The analytical solution for a single pumping well in a uniform flow field as calculated in the computer program DREAM (Round and Bonn, 1994) was used to estimate capture radius. Program input included site-specific hydrogeologic parameters as used in the AT123D model (refer to Section 2.1.2.2) for hydraulic conductivity, aquifer thickness, and hydraulic gradient. For the selected pumping rate of 20 gallons per minute, the resulting well drawdown was about 3 feet with a capture radius of 40 feet (which is a well spacing of 80 feet).

Based on the groundwater capture radius of 40 feet, approximately 16 pumping wells would be required for the two areas. Five soil venting wells should cover the area of soil treatment in the western portion of the site. Separate equipment compounds would be installed in each area. The estimated cost for the capital purchase, installation and operation of a groundwater extraction with soil venting system could range from $400,000 to $510,000. Annual operation and maintenance of the system could range from $90,000 to $110,000. Routine maintenance is required for air strippers (acid wash or replacement), downhole pumps (maintenance/replacement), and liquid phase GAC replacements. This estimate does not consider off-gas treatment of emitted vapors.

5.2.1.2.4 Administrative Considerations

Soil venting w/ groundwater extraction requires the following Administrative Considerations:

- air discharge permitting
- air discharge sampling
- groundwater sampling
- groundwater discharge permitting (storm or sanitary sewer)
- Monthly or quarterly reporting (to client and regulatory agency)
- site safety plan
- engineering / piping, wells, blower, pump design
- engineering operation and maintenance manual
- mass removal tracking

5.2.2 Soil Venting with Air Sparging

5.2.2.1 Description

Air sparging enhances desorption of both adsorbed phase and dissolved phase contaminants in saturated soils and groundwater through volatilization. Sparging involves the forcing of air under pressure through a well screened below the vertical extent of contamination. Dissolved contaminants with high Henry's Law coefficients are volatilized and stripped by the passing air stream and carried into the vadose zone. To be physically removable by sparging, contaminants should have a dimensionless Henry's Law constant >0.01 and a vapor pressure >1 mm Hg. Compounds amenable to air sparging include the chlorinated compounds present at this site including TCE, cis-1,2-DCE.

In order for sparged air to penetrate the soil matrix, hydraulic conductivity should be $>10^{-5}$ cm/sec. In addition, sparging is most efficient when there are no continuous lenses with significantly different permeability in the saturated zone and when permeability in the saturated zone does not increase with depth. Air sparging is often coupled with an SVE technology to control the release of liberated vapors.

This technology is best suited to homogeneous saturated zones, volatile contaminants, saturated thicknesses greater than five feet, and a subsurface geology conducive to capture and control of the liberated vapors. The requirements are reasonably met by site conditions.

5.2.2.2 Soil Venting and Air Sparging Criteria

5.2.2.2.1 Applicability

Air sparging combined with soil venting could be implemented in both areas of concern. Soil venting would be used to control liberated vapors in both areas. It would also be used to address VOCs occurrence in soil in the western area.

The impacted saturated zone at the site mainly consists of homogenous sands with an upper layer of discontinuous silts and clays. The high permeability of the sands is conducive to air sparging. The clay and silt strands may produce channeling through or around these areas. Cyclical sparging should be used at this site to maintain sparging efficiency by limiting the channeling of air. The chemicals of concern are spargeable and the saturated thickness of ten feet or more provides the necessary area for effective air sparing with soil vapor extraction control. The pilot test conducted at the site indicated a sparging radius of influence of 20 feet and a soil venting radius of influence of 28 feet.

No additional water treatment process equipment is required because the combination of air sparging with soil venting does not extract groundwater. This technology may require a barrier groundwater well for additional hydraulic control due to several factors. One factor is possible groundwater mounding and subsequent contaminant migration caused by air sparging. Groundwater mounding is a local increase in the groundwater level caused by the upward pressure of the injection of air into the groundwater. This changes the local direction of flow of groundwater. However, under cyclic operation and low injection pressures, this effect is found to be localized and temporary. Additional factors are the proximity of the creek and the residential neighborhood to the area being treated.

5.2.2.2.2 Protection of Public Health and the Environment

Because of the presence of the clay and silt stringers, additional soil vapor extraction wells [beyond what would be required in a homogenous sand lithology] may be necessary to control liberated vapors along the residential neighborhood perimeter. Sparging causes the vertical movement of contaminants as bubbles move from the saturated zone upward into the unsaturated zone where they are captured as soil gas by the soil venting system. However, when there is a confining layer, such as silt or clay through which the bubbles can not travel, the contaminant bubbles may migrate laterally underneath the confining layer until they can again move upwards to the unsaturated zone. It should be noted that the soil venting radius of influence measured at the site is greater than the sparge radius and conventional system designs extract about three to five times the volume of air that is injected. This practice minimizes or eliminates the possibility of fugitive soil gases migrating into residential areas.

5.2.2.2.3 Cost

Based on an air sparge radius of influence of 20 feet, approximately 30 nested AS/SV wells would be required in the western area and 22 nested wells would be required in the southeastern area. Separate equipment compounds would be installed in each area. The preliminary engineering estimated cost for the capital purchase, installation, and operation of an AS/SV system for one year could range from $410,000 to $460,000. Annual operation and maintenance of the system could range from $65,000 to $95,000. This estimate does not consider off-gas treatment of emitted vapors.

5.2.2.2.4 Administrative Considerations

The following Administrative considerations were identified for soil venting w/air sparging:

- air discharge permitting
- air discharge sampling
- Monthly or quarterly reporting (to client and regulatory agency)
- site safety plan
- engineering / piping, wells, blower, compressor design
- engineering operation and maintenance manual
- mass removal tracking

5.3 Comparative Analysis of Alternatives

There are two major areas of concern at the site. COI are present in the groundwater at both areas above cleanup goals. COI are present above cleanup goals in the soil only in one area. A potential remediation technology must be able to address all phases of interest and be able to bring the dissolved COI concentrations at the property boundary to within levels in a cost-effective manner. The two technologies which have the most potential are soil ventilation with air sparging and soil ventilation with groundwater extraction.

Based on the findings of the technology screening, the two technologies appear to cost approximately the same to design and install. However, permitting, operation, and treatment costs would be higher for the soil vapor and groundwater extraction approach. In addition, the expected life cycle (cleanup time) of the soil vapor and groundwater extraction system would be longer (estimated at least 10 years) than the soil venting and air sparging system (estimated at 3 to 5 years), thereby yielding a much larger total cost. Soil venting with air sparging will not require water management while soil venting with groundwater extraction will. Several options exist with this technology. Both technologies may require vapor treatment prior to discharge. Results of the air sparging with soil venting pilot test indicate this is a feasible technology for the site.

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TABLES

TABLE 1
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

1. Chemical Specific

- ♦ Safe Drinking Water Act (SDWA) (42 U.S.C. 300(f))
  - •National Primary Drinking Water Standards (40 CFR Par 141)
  - •Maximum Contaminant Levels, (chemicals, turbidity, and microbiological contamination) (for drinking water or human consumption) (40 CFR 141.11-141.16)
  - •Maximum Contaminant Level Goals (40 CFR 141.50-141.51, 50 FR 46936)
- ♦ Indiana Drinking Water Quality Standards (327 IAC 8)
- ♦ Clean Air Act (CAA) (42 U.S.C. 7401)
  - •National Emission Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61)
- ♦ Indiana Regulations for Establishing Emission Levels for Volatile Organic Compounds (VOCs) (326 IAC 2 and 8)
- ♦ Clean Water Act (CWA) (33 U.S.C. 1251)
  - •Federal Water Quality Criteria (Section 304)
- ♦ Indiana Department of Environmental Management (IDEM) Voluntary Remediation Program (VRP) (Indiana Code 13-25-5)

2. Action Specific

- ♦ CWA (33 U.S.C. 1251)
  - •National Pollutant Discharge Elimination System (NPDES) Permit Regulations (Section 402 and 40 CFR Parts 122 and 125)
  - •State Enforcement Jurisdiction (40 CFR Part 131)
  - •Sample Preservation Procedures (40 CFR Part 136)
- ♦ CAA Standards of performance for new stationary sources (42 U.S.C. 7411)
- ♦ Resource Conservation and Recovery Act (RCRA) of 1976 (42 U.S.C. 6926(b), Section 3006(b))
  - •Definition and Identification of Hazardous Waste (40 CFR Part 261)
  - •Standards for Generators of Hazardous Waste (40 CFR Part 262)
  - •Standards for Transporters of Hazardous Waste (40 CFR Part 263)
  - •Land Disposal Restrictions (LDRs) (40 CFR Part 268)
  - •Approved State Hazardous Waste Management Programs (Indiana) (40 CFR Part 272.750-272.751, Subpart P)
- ♦ Department of Transportation Rules for the Transportation of Hazardous Materials (49 CFR Parts 107, 171.1-172.558)
- ♦ Occupational Safety and Health Act (OSHA) Regulations for Workers Involved in Hazardous Waste Operations (29 CFR Part 1910)
- ♦ Endangered Species Act of 1973 (16 U.S.C. 1531, generally 50 CFR Parts 81, 225, 402)
- ♦ Fish and Wildlife Coordination Act (16 U.S.C. 661)

- Fish and Wildlife Improvement Act of 1978, and Fish and Wildlife Act of 1956 (16 U.S.C. 742a)
- Fish and Wildlife Conservation Act of 1970 (16 U.S.C. 2901, generally 50 CFR Part 83)
- Farmland Protection Policy Act (7 U.S.C. 4201, generally 7 CFR Part 658)
- Indiana Regulations for Spills of Oil and Other Objectionable Substances: Reporting, Containment and Cleanup (327 IAC 2-6)
- Indiana Regulations for the Treatment and Disposal of Hazardous Waste (329 IAC 3.1)
- Indiana Regulations for the Permitting of Air Strippers (326 IAC 2 and 8)
- Indiana Regulations for Construction Permits for Water Treatment Facilities (327 IAC 3)
- Indiana NPDES Permit Regulations (327 IAC 2 and 5)
- Indiana Regulations for the Registration of Groundwater Extractions Wells Which have a combined capability of pumping greater than 70 gallons per minute (Indiana Code 13-2-6.1)
- Indiana Fugitive Dust Rules (326 IAC 6)
- Indiana Incinerator Rules (326 IAC 4)
- Indiana Final Rules Concerning the Regulation of Water Well Drilling (310 IAC 16)
  - Rules Regarding Permanent Abandonment of Wells (310 IAC 16-10-2)

3. Location Specific

- Construction Within 100-year Floodplain (40 CFR Part 264)
- U.S. EPA's Statement of Procedures on Floodplain Management and Wetland Protection (40 CFR Part 6, Appendix A)[1]
- Indiana Regulations Governing Construction in a Floodway (Indiana Code 13-2-22)
- Marion County Regulations **Governing Construction in a Floodway (Indiana Code 13-2-22)**

4. To Be Considered (TBC) Criteria

a. U.S. EPA RCRA Guidance Documents
   - RCRA Design Guidelines
   - Permitting Guidance Manuals
   - Technical Resource Documents (TRDs)
   - Test Methods for Evaluating Solid Waste

b. U.S. EPA Office of Water Guidance Documents
   - Pretreatment Guidance Documents
   - Water Quality Guidance Documents
   - NPDES Guidance Documents
   - Groundwater Guidance Documents
   - Groundwater Protection Strategy (August 1984)
   - Clean Water Act Guidance Documents

b. U.S. EPA Miscellaneous

- SW-846 Methods - laboratory analytical methods (November 1986)
- Lab protocols developed pursuant to Clean Water Act Section 304(h)
- OSWER Directive 9355.0-28 - Control of Air Emissions from **Superfund Air Strippers**

1 - 40 CFR Part 6 Subpart A sets forth EPA policy for carrying out the provisions of Executive Orders 11988(Floodplains Management) and 11990 (Protection of Wetlands)

TABLE 2
TECHNOLOGY SCREENING MATRIX

NON-TREATMENT SOIL AND GROUNDWATER REMEDIATION ALTERNATIVES

TREATMENT OPTIONS	APPLICABILITY 0 - 5 AP	PUBLIC HEALTH and ENVIRONMENT 1 - 3 HE	ADMINISTRATIVE CONSIDERATIONS (high) 1 - 3 (low) AC	TREATMENT TIME 1 - 3 T	COST 1 - 5 C	RATING SCORE 0 - 360 AP * HE * AC * (C + T)	RETAIN? (Yes / No)
1.0 NO ACTION							
1.1 Leave existing levels in place w/	0	1	3	1	.5	0	NO
long term monitoring							
2.0 CONTAINMENT							
2.1 Groundwater Extraction & Treatment	2	2	2	2	2	32	NO
2.2 Air Sparge Curtain	2	2	2	2	3	40	NO

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LEGEND

APPLICABILITY

0 = Not applicable, available, or implementable
1 = Not widely used and probably not applicable
2 = Widely used but probably not applicable, or not widely used and may not be applicable
3 = Widely used but may not be applicable, or not widely used but probably applicable
4 = Widely used and probably applicable, or not widely used but proven and applicable
5 = Widely used, proven and applicable

HEALTH AND ENVIRONMENT

1 = No control heavy impact and exposure
2 = Extensive impact or exposure with controls
3 = Limited impact or exposure with controls

TREATMENT TIME

1 = Treatment time longer than desired
2 = Acceptable treatment time
3 = Rapid treatment

COST (Capital / Installation / 1 yr O&M)

1 = >$500,000
2 = $300,000 - $500,000
3 = $100,000 - $300,000
4 = $30,000 - $100,000
5 = $0 - $30,000

ADMINISTRATIVE CONSIDERATIONS

1 = Extensive administrative oversight
2 = Normal administrative oversight
3 = Little to no administrative oversight

FLUOR DANIEL GTI

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PREPARED AT GMC COUNSEL'S REQUEST

TABLE 3
TECHNOLOGY SCREENING MATRIX

SOIL and GROUNDWATER TREATMENT--ORGANIC CONTAMINATION

TREATMENT OPTIONS	APPLICABILITY 0 - 5 AP	PUBLIC HEALTH AND ENVIRONMENT 1 - 3 HE	ADMINISTRATIVE CONSIDERATIONS (high) 1 - 3 (low) AC	TREATMENT TIME 1 - 3 T	COST 0 - 5 C	RATING SCORE 0 - 360 AP * HE * AC * (C+T)	RETAIN? (Yes / No)
1.0 VOLATILIZATION							
1.1 Soil ventilation only	2	3	2	1	4	60	NO
1.2 Soil venting with groundwater extraction	5	3	2	2	2	120	YES
1.3 Soil venting w/ air sparging	5	3	2	3	2	150	YES
2.0 EXCAVATION							
2.1 Soil removal and disposal	2	2	3	1	3	32	NO
3.0 EXTRACTION							
3.1 Groundwater pumping only	3	3	2	1	3	72	NO
4.0 DEGRADATION							
4.1 Ozone injection	3	3	2	3	1	72	NO

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LEGEND

APPLICABILITY

0 = Not applicable, available, or implementable
1 = Not widely used and probably not applicable
2 = Widely used but probably not applicable, or not widely used and may not be applicable
3 = Widely used but may not be applicable, or not widely used but probably applicable
4 = Widely used and probably applicable, or not widely used but proven and applicable
5 = Widely used, proven and applicable

HEALTH AND ENVIRONMENT

1 = No control heavy impact and exposure
2 = Extensive impact or exposure with controls
3 = Limited impact or exposure with controls

TREATMENT TIME

1 = Treatment time longer than desired
2 = Acceptable treatment time
3 = Rapid treatment

COST (Capital / Installation / 1 yr O&M)

1 = >$500,000
2 = $300,000 - $500,000
3 = $100,000 - $300,000
4 = $30,000 - $100,000
5 = $0 - $30,000

ADMINISTRATIVE CONSIDERATIONS

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3 = Little to no administrative oversight

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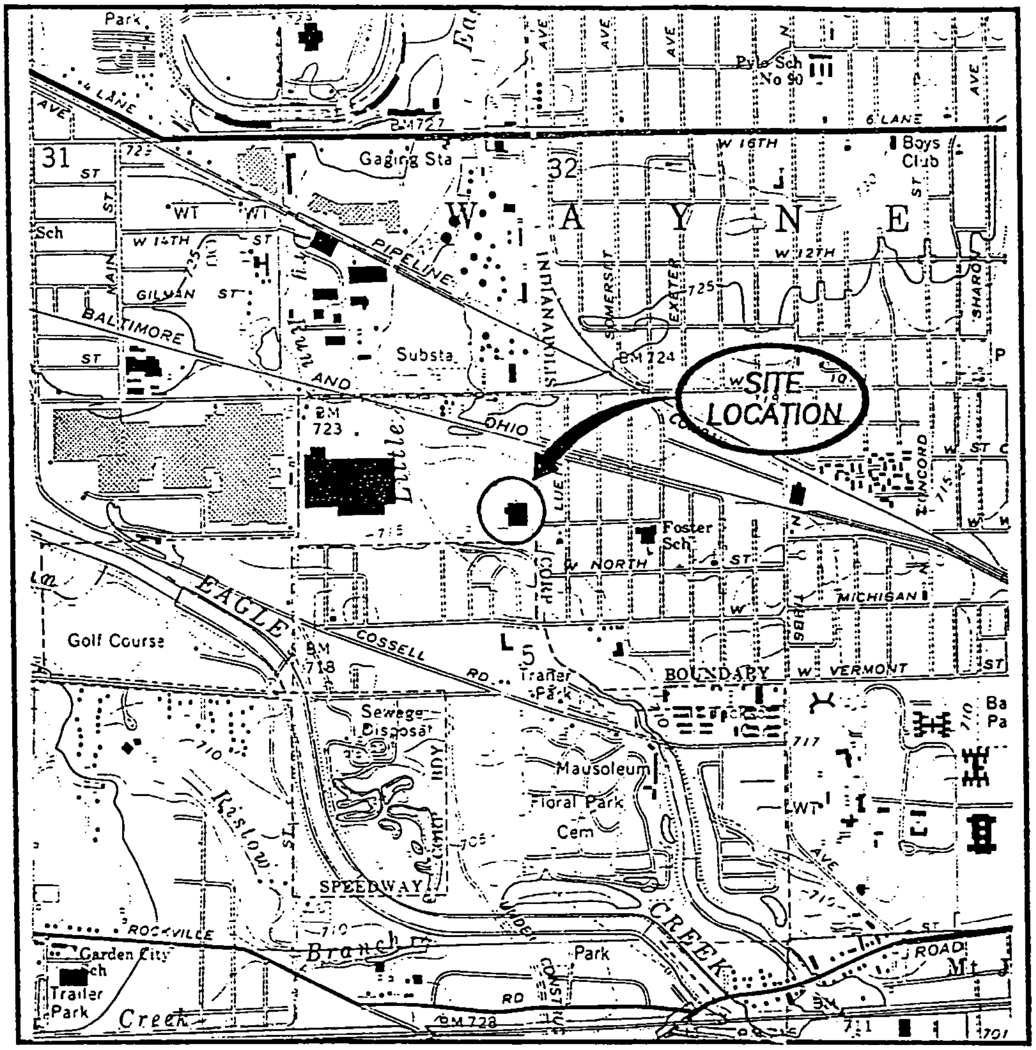
FIGURES



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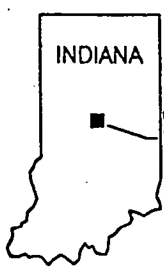

SCALE 1:24,000

0 1/2 1 MILE

0 2,000 4,000

SCALE FEET

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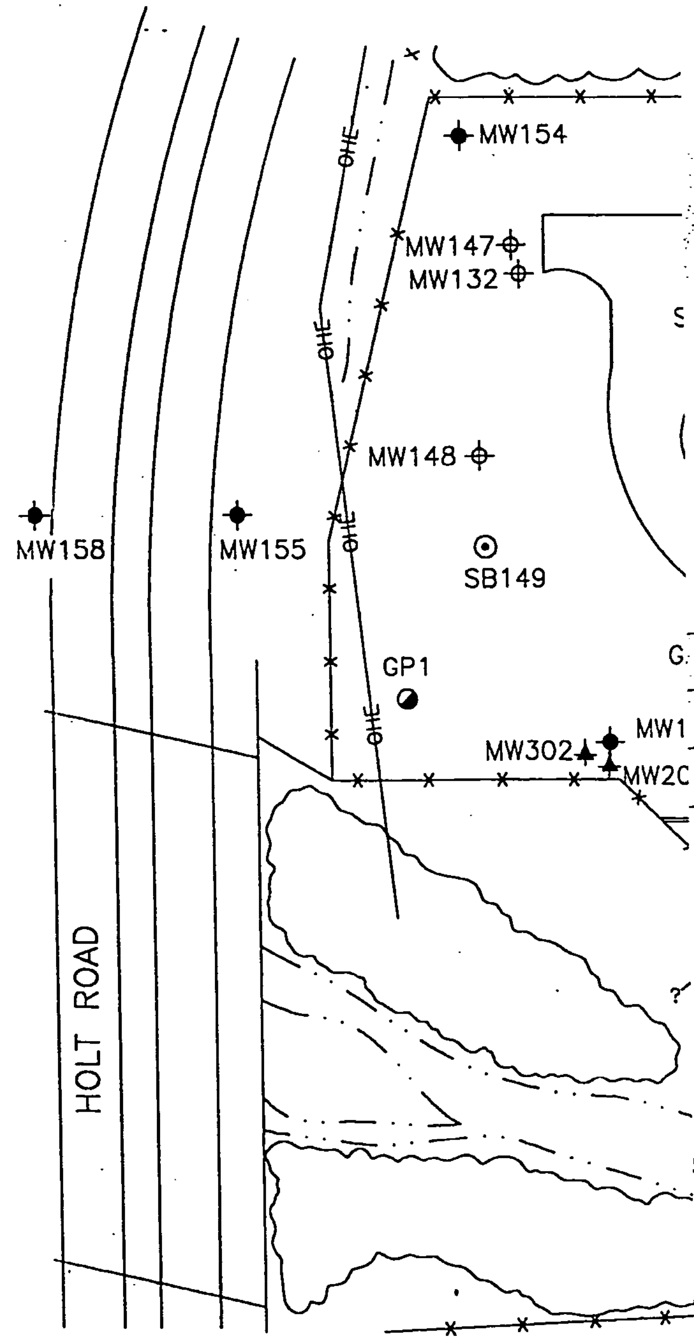
FLUOR DANIEL GTI 6330 E. 75TH ST., STE 176 INDIANAPOLIS, IN 46250 (317) 595-6400	DESIGNED: KG	**SITE LOCATION MAP**
	DETAILED: KG	CLIENT: GENERAL MOTORS CORPORATION ALLISON ENGINE COMPANY PLANT #10 — DRAWING DATE: 6/1/95
	CHECKED:	LOCATION: 700 NORTH OLIN AVENUE INDIANAPOLIS, INDIANA — FIGURE: 1



LEGEND

- NEW SHALLOW 2" MONITORING WELL
- NEW DEEP 2" MONITORING WELL
- NEW AIR SPARGE/ VENT TEST WELL
- NEW 2" OBSERVATION WELL
- NEW HYDROPUNCH POINT
- NEW GEOPROBE POINT
- EXISTING SOIL BORING
- EXISTING MONITORING WELL
- OHE — OVERHEAD ELECTRICAL LINE
- E — ELECTRICL LINE
- G — GAS LINE
- W — WATER LINE

DANIEL QTI

6330 E. 75TH ST., STE 176
INDIANAPOLIS, IN 46250
(317) 595-6400

DRAWING DATE: 2/26/97	ACAD FILE: 0262UTIL

SITE MAP

ERAL MOTORS CORPORATION
N ENGINE COMPANY PLANT #10

700 NORTH OLIN AVENUE
INDIANAPOLIS, INDIANA

PM:	AG
PE/RG:	
DETAILED:	PJC
PROJECT NO.:	040020262
FIGURE:	2

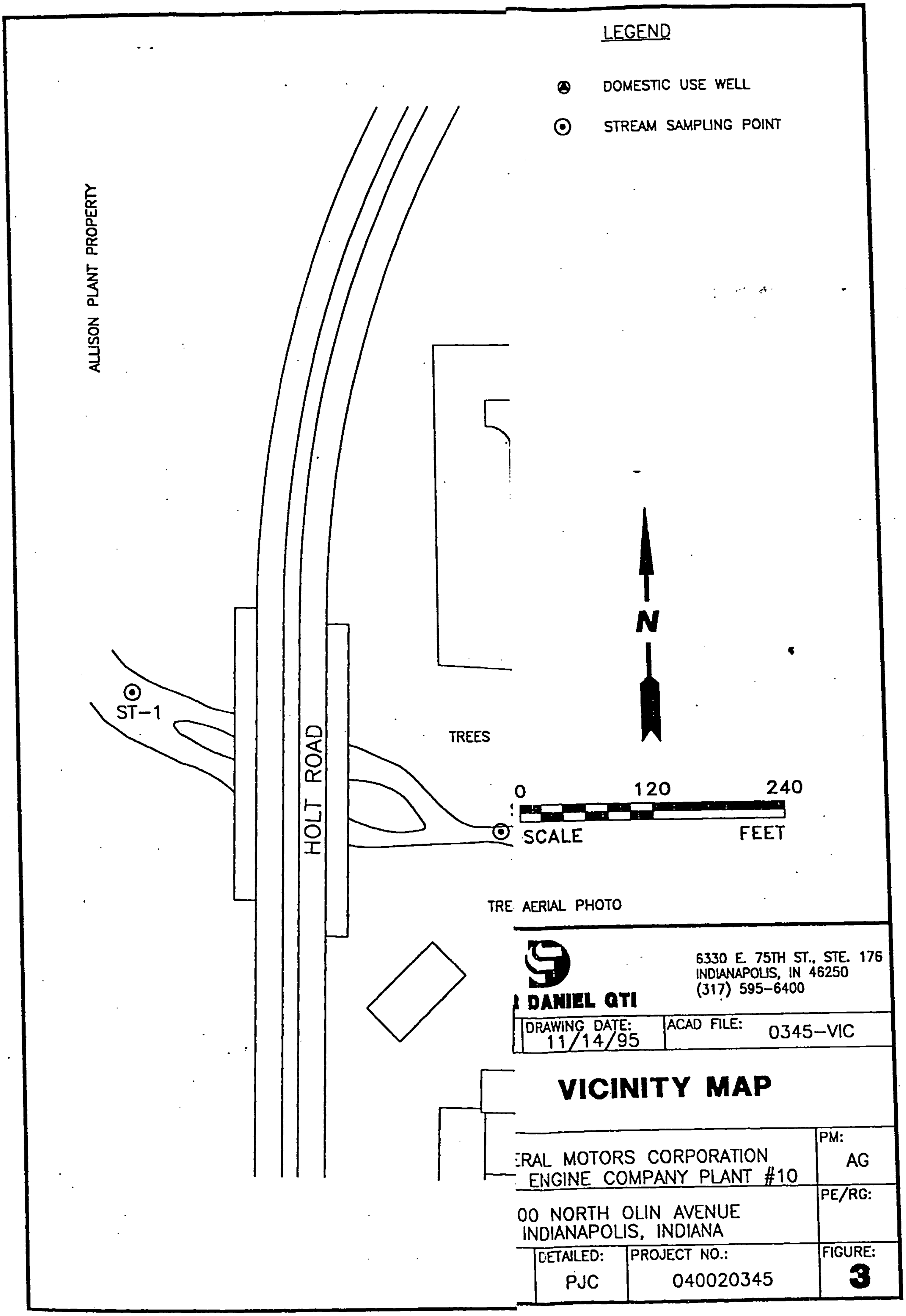
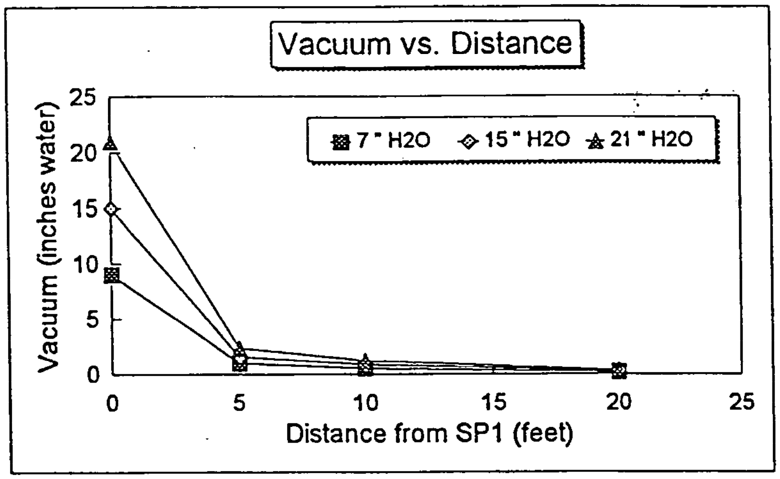
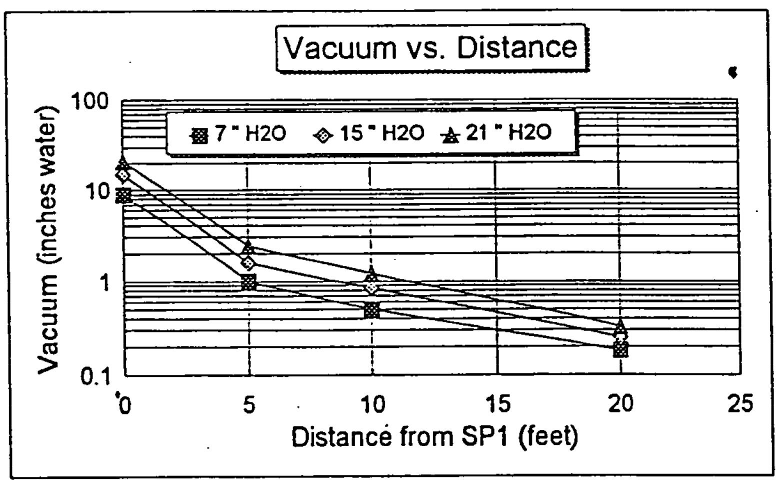

LEGEND
DOMESTIC USE WELL
STREAM SAMPLING POINT
ALLISON PLANT PROPERTY
ST-1
HOLT ROAD
TREES
N
0
120
240
SCALE
FEET
TRE AERIAL PHOTO
DANIEL QTI
6330 E. 75TH ST., STE. 176
INDIANAPOLIS, IN 46250
(317) 595-6400
DRAWING DATE: 11/14/95
ACAD FILE: 0345-VIC
VICINITY MAP
ERAL MOTORS CORPORATION
ENGINE COMPANY PLANT #10
00 NORTH OLIN AVENUE
INDIANAPOLIS, INDIANA
PM: AG
PE/RG:
DETAILED: PJC
PROJECT NO.: 040020345
FIGURE: 3

Figure 4

GM Allison Plant 10

Soil Venting Pilot Test Results





Radius of Influence

Average ROI = 28 feet

Vacuum	ROI (feet)	Correlation Coefficient
7	25.6	0.99
15	27.9	0.99
21	29.4	0.99

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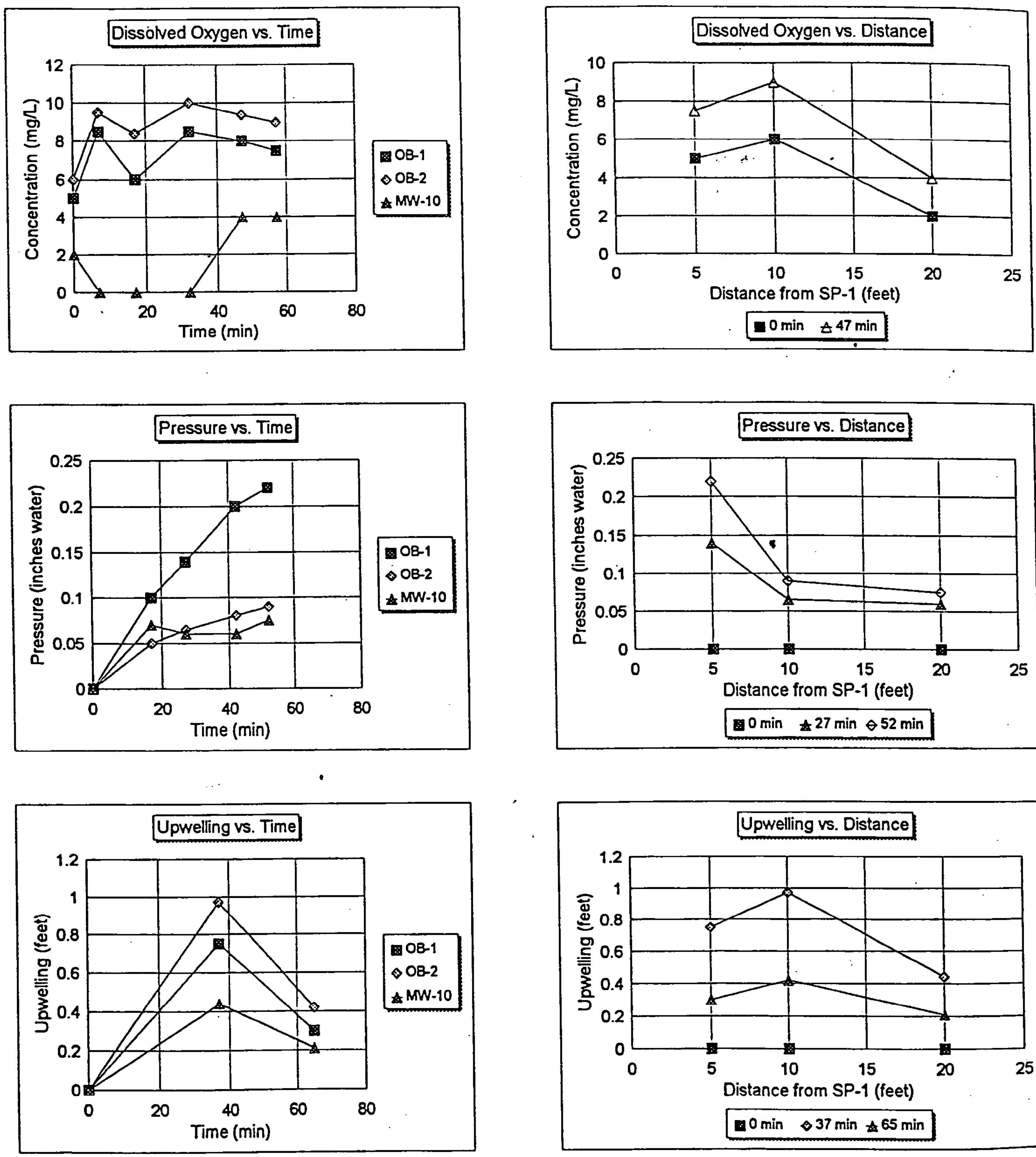
Figure 5

General Motors Corporation - Allison Engine Company Plant 10

Air Sparge Test Results



sparge.